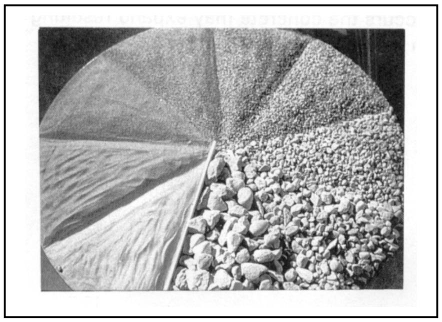
BASICS OF CONCRETE

Introduction

01 Concrete is made up of five primary constituents.

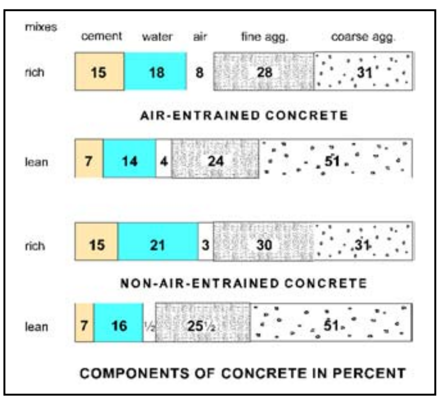
- 02 Water
- Cement
- 03 Air
- Fine Aggregate (FA)
- Coarse Aggregate (CA)



Concrete materials

The water and cement form a paste, which binds the
04 aggregate into a rock-like mass as the water and cement combine through a chemical reaction called hydration. The paste also includes entrapped air introduced by mechanical mixing and entrained air introduced by the addition of chemical admixtures. The paste constitutes between 25 and 40 percent of the volume. The aggregates make up the remaining 60 to 75 percent. Air in concrete varies from about 1/2 to 2 percent in non-air-entrained concrete to about 4 to 8 percent in concrete containing air-entraining admixtures. When designing a mix to handle a specific environmental condition, only
05 entrained air is counted. Entrained air is present in much smaller voids than is entrapped air.

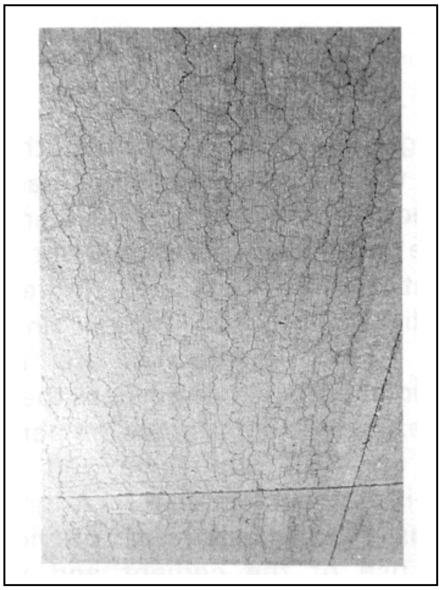
FA, sometimes called “sand”, is composed of particles that pass the 4.75 mm (No. 4) sieve. CA,
06 or gravel, consists of particles retained on or above the 4.75 mm (No. 4) sieve. Well-graded aggregate, consisting of a wide range of FA and CA sizes, provides for efficient use of the water/cement paste. Since aggregate makes up most of the mix volume, it should consist of particles with adequate strength and resistance to exposure conditions.



COMPONENTS OF CONCRETE IN PERCENT

07 Problems with concrete can be categorized in three areas:

- Unsuitable materials
- Improper construction technique
- Environmental conditions

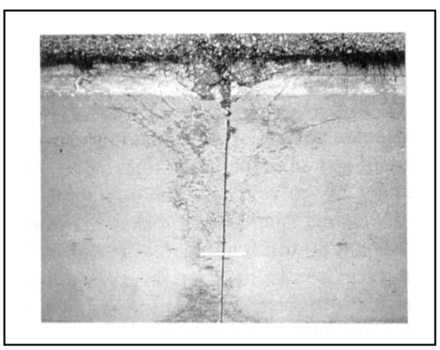


“Map” cracking

Materials selected for a concrete mix have a tremendous impact on the quality of a project. For
08 example, poor quality aggregate raises a number of concerns. Soft aggregates can cause pop outs in the concrete surface. Siliceous aggregates react with the alkali in cement, in a condition called “alkali-aggregate reactivity”, resulting in concrete expansion and “map” or “alligator” cracking. Porous aggregates subject to moisture, along with freeze-thaw cycles, will deteriorate and generate “D-cracking”.

Water/Cement Ratio

The strength of the concrete is determined by the water-cement ratio, that is, the ratio of the mass of water to the mass of concrete. Addition of water above that called for in the mix design will increase the water-cement ratio and adversely affect strength
09 and durability. Advantages of decreasing water content include:



“D” cracking

10
- Increased compressive and flexural strength

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- Decreased permeability (increased watertightness)
- Lower absorption
- Increased durability (resistance to weathering)
- Better bond between successive layers
- Better bond between concrete and reinforcement
- Less bleeding
- Less volume change from wetting and drying

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Considerations in Fresh Concrete

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Concerns with fresh concrete include uniformity, workability, consolidation, and hydration. Fresh concrete should be plastic and capable of being

Measuring slump

molded by hand. Each aggregate particle should be coated with paste and all spaces between aggregate particles should be filled. A well-designed plastic mix keeps the components in place and does not allow segregation during transport. Plastic concrete should not crumble, but flow like a paste.

Uniformity - Fresh concrete should be uniform from batch to batch. To have a finished product that is of consistent quality throughout, each batch of plastic concrete that goes into a structure should be uniform. A commonly used measure of uniformity or consistency is slump. Factors such as water content, temperature, FA content, aggregate shape, air content, and admixtures can influence the slump of concrete. A thorough understanding of factors that can influence slump is important, and a change in slump should not be simply compensated for by varying the water content.

Workability - Concrete should not segregate or bleed water while being worked, but it must be relatively easy to place and consolidate. Transporting and placing fresh concrete as close as possible to its final location will reduce these problems and save resources.

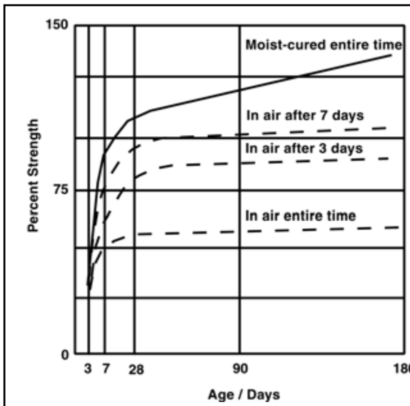
Vibrating cylinder specimens

Consolidation - For concrete that cannot be consolidated manually, vibration sets the aggregate
14 in concrete into motion and allows the mix to become mobile. This allows concrete to mold to forms and around reinforcing. Vibration permits the use of stiff mixtures with a large FA proportion. It also aids in placing concrete of high CA content. The more CA that is used, the less paste is needed since CA has less surface area per unit of mass than does FA. Less paste results in a more economical mix.

Caution must be exercised not to over-vibrate fluid mixes as segregation can occur. Conversely, under-consolidation can result in large voids or honeycombing. The size of entrapped air bubbles, which are relatively large compared with the microscopic bubbles of entrained air, can be reduced by proper vibration.

Improperly consolidated concrete

Concrete core



Strength vs. time and curing

Hydration - The chemical reaction between cement and water is called hydration, and results in the
15 bonding of aggregate particles. Portland cement is an inorganic substance made up of many compounds. The anhydrous (dry) crystalline structure of cement is transformed during hydration to form calcium hydroxide (lime), calcium silicate hydrate, and other components. The concrete properties of set time and strength depend mainly upon the formation of calcium silicate hydrate. Heat is released during hydration, and the rate of the reaction is critical to the quality of the finished concrete. Depending on the chemical makeup of the cement and curing conditions, the rate of hydration and the resulting strength gain can vary significantly.

Strength

16 Strength is usually the primary issue in concrete mix design. Compressive strength is needed for bridges and structures, while flexural strength is needed for pavements and slabs. Concrete has little tensile strength – only about 10 percent of its compressive strength – and almost all structures are designed as though no tensile strength exists. Reinforcement provides needed tensile strength in concrete structures. Flexural strength is normally about 7.5 to 10 times the square root of the compressive strength.

17 The principle factors affecting concrete strength are cement content, water-cement ratio, and age. Compressive strength increases as water-cement ratio decreases, and increases with age. The water and cement in concrete will continue to react as long as there is moisture available and until all the
18 anhydrous cement is consumed. It is critical to keep concrete continuously moist during curing as it will ultimately reach greater strength than concrete allowed to dry. It is important to remember that concrete does not harden by drying. When concrete dries, it ceases to gain strength. Even if it is made wet again, it will not reach the same strength as concrete kept continuously moist.

Density

Concrete that is normally used in highway work has
19 a density (sometimes called unit weight) on the
order of 2320 kg/m^3 (145 lb/ft^3). The density test is used to determine the uniformity of concrete from batch to batch. Factors affecting concrete density include aggregate density, air content, and the water and cement content in the design – all of which are governed by the maximum aggregate size. Density of lightweight concrete can be as low as 240 kg/m^3 (14 lb/ft^3) and that of heavyweight concrete can run as high as 6000 kg/m^3 (375 lb/ft^3).

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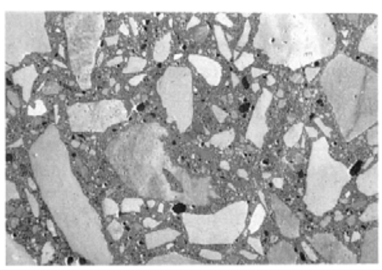
Durability

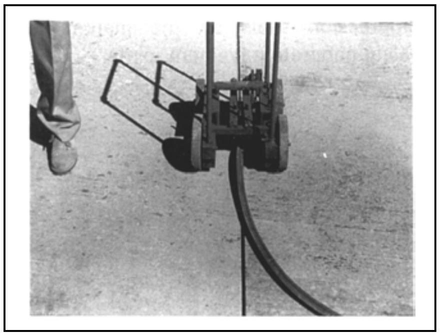


Air voids

21 Durable concrete must have high strength, be
resistant to freeze-thaw damage, have low
permeability, be abrasion resistant, and be resistant
22 to shrinking and cracking. Nondurable, saturated
concrete suffers from deterioration caused by
repeated cycles of freezing and thawing of the water
23 in the concrete paste. With air entrained concrete,
however, resistance to freeze thaw is greatly improved. A network of air bubbles provides space in which water can expand and contract as it freezes and thaws. Concrete made without air entrainment is subject to increased scaling over air entrained concrete.

Concrete exposed to severe weather conditions should have low permeability (be relatively watertight), since water can penetrate permeable concretes. If the water contains a high chloride content, as does sea water, or if roads are salted, reinforcing steel can deteriorate and result in failure of the structure. The permeability of concrete depends on cement content, water-cement ratio, and the length of moist curing. The lower the water-cement ratio, the less water leakage that occurs. The longer concrete is moist cured, the more watertight the concrete will be.

24 A related durability issue is control of cracking. Cracking can be caused by applied loads, expansion and contraction, or drying shrinkage. Proper placement of joints in concrete work can reduce the amount of cracking, particularly if the joints are constructed before contraction or drying occurs. Plastic shrinkage cracks result when water evaporates from the surface of unhardened concrete. This problem is most common when concrete is placed in hot, windy, and/or low
25 humidity weather, and the concrete is not kept moist.



Control joint

Depending on the use of the concrete, abrasion resistance may also be important. Pavements can wear with age, particularly where studded tires are used. Worn pavements can be slippery if the aggregates are easily abraded. Susceptibility to abrasion is influenced by concrete strength and aggregate type.

Summary

High quality concrete requires a proper combination of materials, workmanship, and environmental conditions. The testing technician plays a critical role in helping assure that materials incorporated into a roadway meet the requirements of the proper specification. No combination of proper workmanship and environmental conditions can compensate for poor material quality.